

## CONSTRUCTION SYSTEM

This invention relates to a construction system and in particular relates a construction system using composite materials.

Advanced composite materials have physical properties which make them ideal materials for the building of many types of constructions, particularly houses. They are light weight, typically less than 25% the weight of steel, and yet comparable to steel in strength. As processed they can withstand permanent immersion in water and are not attacked by various types of rot or eaten by termites. If effectively constructed into a house or other building they offer the possibility of structures capable of withstanding earthquakes and hurricanes. If the fibre used in the composite is glass fibre, then the raw material is both abundant and cheap and the glass can be recycled. Composites have excellent creep resistance making them suitable for load application over long periods of time. Thermal properties are excellent offering the possibility of reduced energy demand thus allowing renewable energy sources, such as solar energy, to become a significant source of heating.

Although advanced composites have slowly found new applications, their use in large complex structures such as buildings and houses has been almost non-existent to date. Composite structural elements such as beam sections, for example "I" beams, angle sections, and box beams, have been manufactured by the "pultrusion" process for many years, but have proved difficult to fasten together. Composites do not plastically deform like metals and therefore cannot be as effectively fastened together using bolts, screws or rivets. Furthermore they cannot be welded. The lack of effective fastening methods has severely restricted growth in the use of advanced composites despite their excellent physical properties.

The object of this invention is to provide a system of composite structural elements and methods of construction that effectively fuse the structural elements into a single complex

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advanced composite structure, suitable for many applications but particularly suitable for the construction of houses or other buildings.

In its broadest aspect the present invention provides a method of building which comprises taking honeycomb panels (as hereinafter defined) having at least one flat edge for bonding to an adjacent structural unit, and bonding the panels and/or units together to form a composite building structure.

The adjacent structural unit may be another honeycomb panel, or a beam, corner, or other desired unit as will be described more fully hereinafter.

An analysis of a typical wall, as shown in figure 1 of the accompanying drawings, shows that any structure of this type contains three fundamental elements, panels, beams and corners. Any construction system must therefore effectively provide these elements.

Manufacturing large composite panels using conventional sections is difficult as flat sheets of material are not sufficiently rigid and a lot of additional support structure must be added to achieve the desired rigidity of a wall panel. This problem is overcome by the honeycomb panel of our European patent number 0 708 706. The honeycomb configuration of this structure makes it an ideal panel and it can be manufactured in an open or faced panel format. Furthermore it can be made in large sizes for example 0.9m x 2.5m and 40mm thick. The panel can be modularised by constructing the fibre reinforcement into a narrow width panel preform, say 300mm wide. At the moulding stage three fibre preforms can be loaded into an appropriate mould tool and a panel made of 900mm width. A further property of the panel is that it acts like a beam in all directions, but is particularly effective as a beam when loaded on its edge as illustrated in figure 2 of the accompanying drawings. The construction of the panel may be such that the honeycomb format is always integrated into and bounded by a continuous straight edge. By effectively fastening a composite beam section such as a flat plate or box section to the edges of the panel, the properties of the panel, functioning as a beam, can be so enhanced as to make it effectively a beam, as illustrated in figures 3 and 4 of the accompanying drawings.

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The honeycomb panel therefore provides two elements of the wall, namely the panel and the beam. The third element, that of corners, can be solved by the use of a box section. A box section by definition has a number of faces, typically four, but can be three or more than four. In figure 4 of the accompanying drawings three panels are shown attached to a single four sided box beam.

The box beam therefore acts as a corner allowing the panels in effect to change direction e.g. by 90°.

The honeycomb panel is preferably bounded on all four sides by flat edges and can therefore be fastened to other panels or beam sections or a combination of both. Hence by combining these elements the construction of complex structures is possible and the requirement for panels, beams and corners is fulfilled.

A property of the honeycomb panel is that it can be made as an open structure and an alternative construction method would be, in for example a cavity wall, for the inner panel to be of open structure and a facing board bonded directly onto it in situ. The facing board could be plasterboard, fabric covered board, or any desired decorative or fastened surface.

It has been demonstrated that by a combination of honeycomb panels and beam sections complex structures can be created, however a method of effectively fastening these elements together is required and the resultant structure must be examined to determine if additional structure in the form of brackets is required.

An advantage of composites is that they can be very effectively bonded by modern adhesives to the extent that the joint becomes as strong as the base material. Furthermore the honeycomb panel is preferably always bounded by a flat face which can mate with a flat face of another panel or a beam section. There therefore exists an opportunity to create a bonded joint at the interface of these flat surfaces.

A correctly constructed joint would in effect "weld" the elements of the system together allowing them to function as a single element. Such a joint would also be water-tight.

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According to a second aspect of the present invention there is provided a method of joining adjacent structural units which comprises providing an abutting edge of an end unit with a slightly recessed area capable of receiving adhesive extending across less than the width of the edge, and at least one more greatly recessed area capable, either alone or in combination with the corresponding area of the abutting unit, of forming a gallery for rapid transit of adhesive along substantially the entire abutting surfaces.

In a preferred embodiment of the second aspect of the invention, one or both abutting surfaces may be provided with heating elements to achieve rapid cure, even in cold conditions.

According to a third embodiment of the invention, the panels and other units may be made from a thermoplastic resin and heating elements provided to fuse adjacent abutting surfaces together by localised melting of the material.

According to a fourth embodiment of the invention there is provided a method of making a cavity wall which comprises taking two or more honeycomb panels and locating them in spaced apart relationship by means of a recess or raised area in a unit abutting at least one edge of the panel and bonding the panels to the unit.

In the construction of buildings and in particular houses it is an advantage if the walls can be of a cavity construction. The cavity offers the facility to add insulation and run services such as electricity wires, telephone wires and pipe work within the wall thus hidden from view. Using the honeycomb panel with faced surfaces and by arranging the faced surfaces to face to the outside, a cavity wall can be created. The unit may be a corner and is preferably recessed to locate the panels.

A fifth embodiment of the invention provides a method of forming a casement for a window, door or the like, in a cavity wall according to the fourth embodiment, comprises forming a hole of the desired size whether by omitting a panel or cutting an existing panel, and sealing and retaining the edges of the hole by applying a shaped strip which grips the panels, and bonding the strip in place.

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In the case of a single leaf wall, a simpler strip may be employed which encapsulates the edge of the (single) panel.

According to a sixth embodiment of the invention there is provided a ferrule for sealing a beam to a beam or other unit which comprises a block of material shaped to fit partly within a beam end where it can be bonded, having an end surface capable of being bonded to a flat surface of a beam or other unit.

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic perspective view of two walls of a building;

Figure 2 illustrates the honeycomb panel or a beam;

Figures 3 & 3a expand on figure 2;

Figure 4 shows panels attached to a square beam;

Figures 5, 5a & 6 illustrate a cavity wall according the invention;

Figures 7 & 8 illustrate the method of joining in accordance wit the invention;

Figures 9 & 10 illustrate the welding of thermoplastic units;

Figures 11 to 15 illustrate the joining of beams; and

Figures 16a, b & c illustrate the formation of casements for windows and the like.

Referring to three drawings, figure 1 illustrates the beam 10, panels 12 and corners 14 required in any building system.

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Figures 2, 3 and 3a show a honeycomb panel 12 in accordance with EP-A-0708706 acting as a beam and indeed being formed into I-beams by the bonding thereto of flat members 16 (which can themselves be honeycomb panels).

Figure 4 shows a square corner 14 having three panels 12 attached thereto.

Figures 5 and 6 illustrate the cavity wall of the invention in which two panels 12 are held in spaced apart relationship by a beam 18 having a raised area 20 which locates and supports the panels. The panels are then bonded to the beam 18 to form the wall. There may be beams 18 on all four sides of the wall thereby sealing it, or other units may be used. In figure 6 the honeycomb structure 22 can be seen where a facing panel 24 is cut away. The panel 24 can be omitted on the insides of the wall, and inner and outer panels may be, and indeed are likely to be, different from one another as one may need to be weather resistant and the other carrying a decorative finish, for example. In the construction of figure 5a, 'I'-beam spacers 25 are employed, preferably bonded to the respective inner faces of the panels 12. The spacers 25 may be of composite material or of other suitable material such as aluminium. The spacers lock the respective faces together and greatly increase the strength of the wall. This construction may be employed for very high stress-bearing wall, e.g. those carrying kitchen units or cupboards, or for buildings in areas exposed to hurricanes.

The honeycomb panels and beam sections are preferably a composite of, typically, glass fibres and acrylic based resin. At the interface of a panel and beam a joint 26 is formed as shown in figure 7. Half of the joint 26 is provided in each element being bonded and consists of a glue line 28, two sealed edges 30 and a gallery 32. At suitable locations along this joint, vent holes and injection holes are provided as necessary. The joint 26 is made as follows. The panels and beam elements are assembled and temporarily held in their respective locations in a fixture or with clamps and simultaneously all joint edges are sealed.

An adhesive, for example of the type supplied by Permabond and designated 5002, also an acrylic based resin, is injected under pressure directly into the gallery 32 of the joint 26.

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The resin is then distributed into the glue line 28 from the gallery 32 and air is expelled through the vents. On completion of the injection, signified by resin appearance at the vents, both vents and the hole for the nozzle are plugged off with small plastic plugs. This type of adhesive will cure sufficiently, at 20°C, within 15 minutes to a point where the structure will be self supporting and can be removed from a fixture or clamps removed as appropriate. The glue line 28 is continuous around the contact surfaces and because it has been filled by adhesive under pressure, the joint will be completely water tight. Hence structures which are required to hold water or repel water such as roof structures can be produced. The joint edges 30 are sealed by placing a gasket material on the appropriate edge prior to assembly. Companies such as Permabond & Loctite supply a wide range of suitable material.

If assembly is occurring at low temperatures, resistance type heating elements 34, which in reality are very thin wires, can be incorporated into the face of the glue line of the panel (fig 8). These can be activated at the time of injection and for a short period after to ensure a full cure of the adhesive.

Although the composite described, consists of glass fibres and a thermosetting resin, advances in plastic materials and development of new fibres might make it possible to reproduce the elements of the construction system with sufficient mechanical strength as to make them a viable proposition using thermoplastic material. Thermoplastics are, however, difficult to bond with adhesives and the joint described would not work. Alternative joints will now be described which allow the structural elements to be welded.

In the first instance heating elements 34 are moulded into or bonded onto the jointing face of the honeycomb panel (or the beam), as shown in figure 9. The elements are then heated by passing an electric current through them and as the contact face melts the panels and beams sections are compressed together effectively welding them together. This method is capable of producing an excellent joint but requires movement of the components. A second joint which allows fixed clamping will now be described.

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Again heating elements 34 are provided in the joining face of the honeycomb panel 12. In addition, in the centre of the joint, a groove 36 is provided into which a plastic strip 38 is located, (fig 10). The plastic strip contains a heat activated foaming agent which when heated expands. As the joint is heated by the elements and becomes liquid the expanding plastic strip pressurises the liquid forcing it in contact with the face of the mating component thus causing a good welded joint. The heating elements 34 are positioned so as not to melt the extreme edges of the panel thus allowing the edges to retain the melted plastic within the joint. Joints of the type described could be made in less than 5 minutes and would provide a very rapid assembly method.

Referring now to figures 11 to 15, the joining of beams is considered. In situations where a box section butts up to the side of a beam and honeycomb panels 12 are bonded to both beams (fig 13), the panel 12 acts itself as a corner bracket and no additional bracket is required. If, however, due to structural or sealing considerations an additional bracket is required, this can be achieved by a ferrule plug bracket (fig 14) which works as follows. A bracket 40 is moulded from a similar composite to the other structural elements and is bonded to the end of the beam section 10 which forms the butt joint as shown in figure 14. The beams and honeycomb panels are then assembled and at the same time the ferrule plug bracket 40 is bonded onto the adjoining beam, a suitable adhesive again being Permabond 5002. This type of bracket seals the butt joint of beam to beam, strengthens the open end of the beam and makes use of the large available surface area within the beam to achieve a very strong joint. Externally the bracket and beam appear as a continuation of the beam and the joint continuity between beams and honeycomb panels is maintained. The area 42 is spread with adhesive and bonded to the inside of the beam 10 while the area 44 is spread with adhesive and bonded to the external surface of corner 14.

In situations where a beam has to be joined to another length of beam a joint 46 can be made using a short length of beam which just slides inside the larger main beam, (fig 15). The joint is bonded into place in one of the two beams and then the second beam is slid over the projecting portion of the joint and bonded in place to form a butt joint. Connecting honeycomb panels to the beam such that they overlap the join further strengthens the join. A suitable adhesive would again be Permabond 5002.



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In situations where simple brackets such as angle brackets are required, these can be bonded, or bonded and screwed, to the composite structure. Aluminium can also very effectively be bonded to the composite particularly with acrylic adhesives of the type Permabond 5002. Aluminium beam sections could be used in place of the composite beams and there are potential applications for this substitution.

The composite structure so far described has not addressed how to create openings for doors and windows. In figure 16a a cavity wall is shown with partial window opening together with a shaped strip section 50 providing the casement for a window. The shaped strip has the profile illustrated in figure 16c and as can be seen comprises two recesses 52 which grip the respective leaves 12 of the cavity wall, separated by a spacer section 54 to separate the panels 12. The construction of the inner facing surface of the strip 50 is determined by the window or the like to be fitted into the casement opening. The assembly procedure would involve clamping all the elements together and injecting adhesive into a glue line created in the honeycomb panel and shaped strip (similar to that described hereinabove). The ends of the shaped strip section are pre-bonded on assembly thus sealing the glue line.

Now if a window or door aperture is cut out of the honeycomb panel, which is possible using conventional routing equipment and diamond cutters, the exposed edges of the honeycomb would be present and no glue line joint is available (fig 16b). By using the same shaped strip it is possible by applying adhesive to all the surfaces in contact with the section to achieve an excellent joint, even though this is not continuous. The strip is so designed as to encapsulate each panel thus tying the two panels together and retaining a high degree of structural integrity. Window and door frames can be directly attached to the casement opening so made.

Although the panels of the invention have been described with respect to walls, it will be appreciated that they can be used in any building or construction end-use, e.g. floor panels, roofing panels, or the like.

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The invention provides a construction system capable of using largely factory pre-formed parts and quickly and cheaply erecting a building which is immensely strong, being effectively of an integral monocoque construction, as well as being rot- and insect- proof.

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